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Cues used by house finches for detecting methiocarb-treated grapes

MARK E. TOBIN

Division of Wildlife and Fisheries Biology, University of California, Davis, CA 95616, USA

ABSTRACT. Laboratory tests were conducted to determine how house finches (*Carpodacus mexicanus*) detect and avoid bunches of grapes treated with the repellent methiocarb and to determine whether the presence of a visual tag paired with methiocarb-treated bunches facilitates this detection and avoidance. Individually caged birds were offered one untreated and one treated grape bunch during a series of 2 h preference feeding trials, and each bird's total consumption and its preference for the treated bunch were measured. When the positions of the treated and untreated bunches were alternated during successive feeding trials, house finches took just as much from the methiocarb-treated bunch as from the untreated bunch, but their total consumption declined. When the positions of the treated and untreated bunches were kept constant, total consumption initially declined but increased again to pretreatment levels as the birds learned to feed from the non-treated bunch. Consumption from the grape bunch on the side of the cage where the birds had previously encountered the repellent remained low even after methiocarb treatments ended. The visual tag had little effect on either total consumption or grape bunch preference. The implications of these findings for controlling bird damage to ripening grapes are discussed.

Introduction

House finches cause considerable damage to ripening grapes in California (DeHaven, 1974; Crase, Stone, DeHaven and Mott, 1976), and more effective methods are needed for reducing this damage. Chemical repellents such as methiocarb (4-methylthio-3,5-xylyl methylcarbamate, Mesurol®) might provide a way of controlling losses with minimal adverse impacts on bird populations. Field tests have shown that methiocarb can reduce overall bird damage in wine grape vineyards (Bailey and Smith, 1979; Hothem, Mott, DeHaven and Guarino, 1981), and tests with caged birds have demonstrated its effectiveness against house finches in particular (Tobin and DeHaven, 1984).

Methiocarb elicits conditioned food aversions in birds (Rogers, 1974). This chemical interferes with the transmission of nerve impulses (Schlagbauer and Schlagbauer, 1972), and animals that ingest food treated with methiocarb may lose partial or total control of their muscles. After ingesting sub-lethal doses and suffering from its deleterious effects, animals learn to avoid treated food in the future. An important aspect of such conditioning is that animals associate certain critical cues (conditioned stimuli = CSs) with the harmful effects after ingestion (unconditioned stimuli) produced by the repellent (Garcia and Hankins, 1977). This presumably allows the animals to perceive the presence of the chemical and so reduce or avoid consumption of it in the future.

CSs used in food aversion learning vary among both bird species and types of food. Many birds recognize harmful foods by sight (Brower, 1969; Wilcoxin, Dragoin and Kral, 1971; Logue, 1980; Nicolaus, Cassel, Carlson and Gustavson, 1983), but taste may be more important for some birds (Brett, Hankins and Garcia, 1976; Shumake, Gaddis and Schafer, 1977). Often both taste and sight play a part in food aversion learning (Brower, 1969; Jones, Bellingham and Martin, 1978; Clarke, Westbrook and Irwin, 1979; Lett, 1980; Westbrook, Clarke and Provost, 1980), and the relative importance of these two senses may depend on the nature of the substance ingested (Gillette, Martin and Bellingham, 1980; Gillette, Irwin, Thomas and Bellingham, 1980).

The specific manner by which house finches detect methiocarb-treated grapes is as yet not well understood. More knowledge of what kinds of CS they associate with the ingestion of methiocarb-treated grapes could facilitate the development of more effective strategies for using this repellent. Visual cues have been used to enhance the repellency of methiocarb-treated food to quelea (*Quelea quelea*) (El Mahdi, 1982), red-winged blackbirds (*Agelaius phoeniceus*) (Mason and Reidinger, 1983a,b), and silvereyes (*Zosterops lateralis*) (Rooke, 1983), and they might also be effective against house finches. Pairing additional CSs with applications of methiocarb not only might enhance repellency but also might reduce the amount of repellent necessary to protect the crop. This would save money for the farmer and also would reduce the amount of the chemical introduced into the environment.

I report here a study designed to evaluate visual tags (markers) paired with methiocarb-treated grapes that were provided for house finches. The objectives were to determine: (1) whether house finches can discriminate between untreated grape bunches and grape bunches treated with methiocarb; (2) whether the pairing of visual tags with treated grape bunches enhances this discrimination; (3) whether visual tags alone repel house finches that previously have been given methiocarb-treated grape bunches paired with the visual tags; and (4) the importance of locational cues for identifying grape bunches treated with the repellent.

Methods

Captive wild house finches were kept for about 12 months in a $4{\cdot}9 \times 2{\cdot}5 \times 2{\cdot}5$ m communal outdoor cage before testing, and provided with a mixture of seeds (millet, sorghum, sudan grass, watergrass, and sunflower), grit and water *ad libitum*.

The house finches were transferred indoors and kept visually isolated in individual $0{\cdot}61 \times 0{\cdot}61 \times 0{\cdot}61$ m wire cages for 1 month before testing. The daily photoperiod was 12 h/12 h light/dark, and the ambient temperature was 18–22°C. The same maintenance food as supplied in the communal cages was provided *ad libitum*.

The experiment consisted of a series of daily 2 h grape feeding trials during which the maintenance food was removed from each cage and two grape bunches large enough to permit the birds to feed *ad libitum* were suspended above the perch. The first four such feeding trials were conducted from 21 to 24 October 1982 to accustom the birds to the test procedures, and no treatments were applied to the grape bunches. Testing then started on 25 October 1982 and consisted of three test phases, with each phase comprising six feeding trials. The feeding trials were conducted on consecutive days except that 2 days elapsed between the first and second phases of the test.

On the day before each feeding trial, 15 min before the onset of the dark period, maintenance food was removed from each cage. The next morning, 1·25 h after the start of the light period, two bunches of grapes, one treated and one untreated, were weighed and suspended from the top of each cage. Two hours later, these bunches were removed and reweighed, and the maintenance food replaced. Weight loss due to dehydration was evaluated during each feeding trial by weighing two grape bunches hung in an empty cage.

Five males and five females were randomly assigned to each of four treatment groups for testing. All four groups of birds were tested during phase 1, but only groups 1 and 4 were tested during phases 2 and 3 (Table 1). Two birds died during the course of the test, one due to an accident not related to methiocarb poisoning and the other from unknown causes. These birds were not replaced.

TABLE 1. Treatments applied to one of two grape bunches offered to individually caged house finches

	Phase of test		
Group	1	2	3
1	Water	Methiocarb & visual tag	Visual tag
2*	Methiocarb		
3*	Methiocarb & visual tag		
4	Visual tag	Methiocarb	None

*Tested during phase 1 only.

The four treatments were water only, methiocarb only, methiocarb plus visual tag, and visual tag only (Table 1). The grapes were treated with methiocarb 1·5 h before offering them to the birds, by immersing the individual bunches for 3 s in a suspension containing 2·0 g methiocarb (using Mesurol 75% WP) in 2·0 ℓ deionized water. Bunches treated with water only were simply immersed for 3 s in 2·0 ℓ of deionized water. Bunches were then placed in a well-ventilated area to dry. The visual tag was a 7·6 × 3·8 cm piece of yellow cloth tape folded in half over the handle of a paperclip and marked on each side with a brown 'X'. For the appropriate bunches, the visual tag was clipped around the wire hook supporting the grape bunch.

During actual testing, the position of the treated bunch (left or right side of cage) was randomly selected for each bird in such a way that half of the birds in each treatment group had the treated bunch on the right side of the cage and half had the treated bunch on the left for the first feeding trial. The positions of treated and untreated bunches were then alternated during the successive feeding trials of phase 1 and the first feeding trial of phase 2. The positions of the bunches were not alternated during the remainder of phases 2 and 3.

Zinfandel wine grapes were used for the test, and all bunches were kept frozen until the day before being used in a feeding trial. The two bunches for each bird for each feeding trial were as similar as possible in size and appearance. The amount of soluble solids, an indication of the sugar content of the grapes, was estimated by taking a refractometer reading of grape juice (Nelson, 1979). For each bird and feeding trial, only those bunches were used whose sampled berries had refractometer readings >18 degrees Brix and differed by <2 degrees.

An analysis of variance (ANOVA) (Bryce, 1980) was used to examine separately two subsets of data resulting from this test. One analysis included the data for all four treatment groups during phase 1 only. A two-way ANOVA with repeated measure of individual birds was used, with treatment group and feeding trials as independent variables. The other analysis included treatment groups 1 and 4 only during all three phases of the test. A three-way ANOVA was used, with treatment group, phase, and feeding trial nested within phase as three independent variables. For both analyses, two dependent variables were (1) the square root of the total consumption (the net weight lost from both grape bunches) and (2) the arcsine square root transformation of the preference score (the proportion of weight consumed which was from the treated bunch). The Bonferroni upper bound to the significance level (Miller, 1981) was used to make within-group pairwise multiple comparisons between feeding trials and within-feeding trial multiple comparisons between groups.

Results

Phase 1—all four treatment groups

During phase 1 there was little evidence that house finches detected methiocarb on the grapes or that the visual tag facilitated recognition of the methiocarb-treated bunches. The average preference scores of each group are shown in Figure 1. Overall variation among the four treatment groups was significant ($F_{3;35}=3{\cdot}97$, $P<0{\cdot}025$), but there were few consistent differences among the four groups. None of the pairwise multiple comparisons between groups was significant ($P>0{\cdot}05$), and during most of phase 1 the two groups offered methiocarb-treated grapes took proportionately just as much from the treated bunch as the two groups without methiocarb (Figure 1).

Total grape consumption during phase 1 varied significantly among the four groups of birds ($F_{3;35}=7{\cdot}96$, $P<0{\cdot}001$). Groups 2 (methiocarb) and 3 (methiocarb plus visual tag) each consumed significantly less than either group 1 (water) ($t_{175}=7{\cdot}21$ and $7{\cdot}47$ for groups 2 and 3, respectively, $P<0{\cdot}05$) or group 4 (visual tag) ($t_{175}=6{\cdot}83$ and $7{\cdot}08$ for groups 2 and 3, respectively, $P<0{\cdot}05$). Consumption apparently was not affected by the visual tag because there were no significant differences either between groups 1 and 4 (the two groups without methiocarb) ($t_{175}=0{\cdot}39$, $P>0{\cdot}05$) or between groups 2 and 3 (the two groups exposed to methiocarb) ($t_{175}=0{\cdot}06$, $P>0{\cdot}05$).

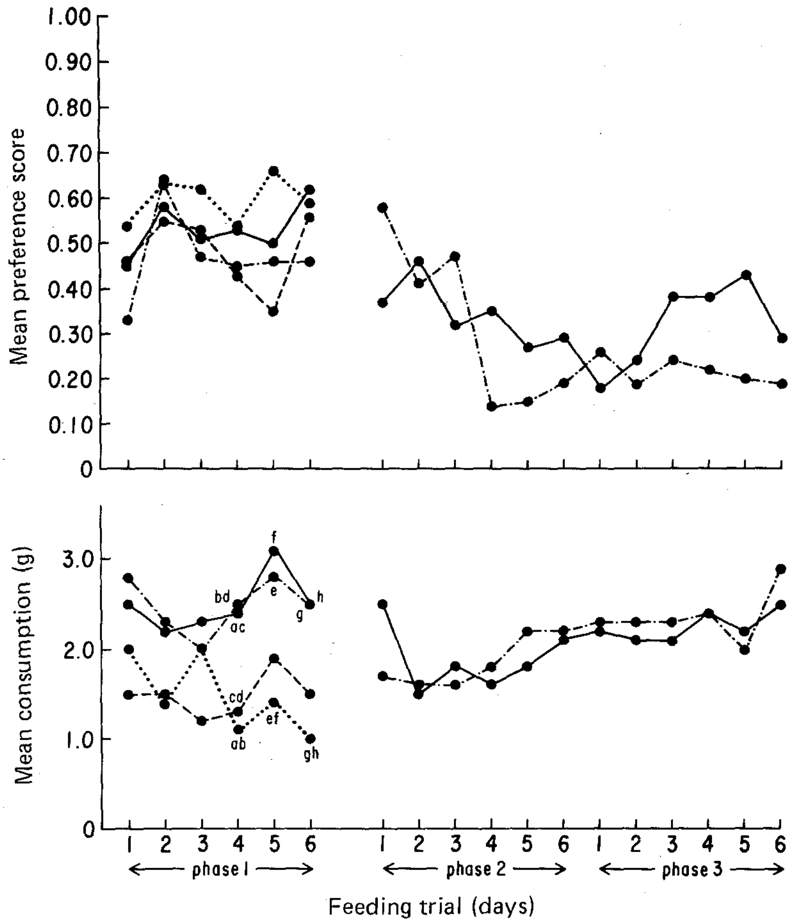

FIGURE 1. Mean preference scores and grape consumption for various groups of house finches during each of 18 2 h feeding trials. For grape consumption, means with the same letter are significantly ($P<0{\cdot}05$) different from each other. The Bonferroni t test was used to compare means. ●——● Group 1; ●- - - -● group 2; ●······● group 3; ●—·—● group 4 (for treatments see Table 1). For all groups, $n = 10$.

Phases 1, 2, and 3—treatment groups 1 and 4 only

Discrimination between methiocarb-treated and untreated bunches improved when the locations of the treated and untreated bunches were not alternated during successive trials. During phase 2, the birds shifted their feeding away from the methiocarb-treated bunches, and preference scores declined (Figure 1). Overall, preference scores varied significantly during the three phases of the test ($F_{2;35}=10{\cdot}11$, $P<0{\cdot}001$). However, none of the multiple comparisons between phases was significant ($P>0{\cdot}05$), probably because preference scores remained relatively high until after the third feeding trial of phase 2.

Overall, there was a significant effect due to feeding trial ($F_{15;265}=1{\cdot}70$, $P<0{\cdot}05$). The greatest effect seemed to be during phase 2, when the birds were exposed to methiocarb. The average preference scores of both groups generally declined during phase 2, indicating that as the birds were repeatedly exposed to the repellent, they improved their discrimination of treated versus untreated bunches (Figure 1).

The visual tag did not seem to help the birds to distinguish between treated and untreated bunches, because there were no significant differences between the preference scores of groups 1 and 4 ($F_{1;18}=1{\cdot}46$, $P>0{\cdot}10$).

Preference scores remained low even after methiocarb was no longer present on the grapes. The average preference scores of group 4 remained uniformly low throughout the six trials of phase 3, but those of group 1 increased somewhat after the second feeding trial of the third phase (Figure 1). Yet even in group 1, several of the birds consistently had low preference scores throughout phase 3. During the sixth trial, five birds in each of the two groups took $<10\%$ of their grapes from the side of the cage formerly associated with methiocarb.

Total consumption varied significantly during the three experimental phases ($F_{2;35}=12{\cdot}73$, $P<0{\cdot}001$) (Figure 1). Overall, the birds ate significantly less grapes during phase 2 (when they were exposed to methiocarb) than during either phase 1 ($t_{35}=3{\cdot}37$, $P<0{\cdot}05$) or phase 3 ($t_{35}=2{\cdot}99$, $P<0{\cdot}05$) (when methiocarb was not present). Total consumption during phases 1 and 3 was not significantly different ($t_{35}=0{\cdot}34$, $P>0{\cdot}05$).

The visual tags again apparently did not have any effect on consumption because there were no significant differences between the groups with and without the visual tag ($F_{1;18}=0$).

Discussion

When discrimination between methiocarb-treated and untreated bunches was poor, the birds developed a general aversion to both bunches. When discrimination improved, the birds developed a specific aversion and reduced their feeding only from the bunches treated with methiocarb. During phase 1, grape consumption for the two methiocarb groups was consistently reduced from both bunches. During phase 2, total consumption for groups 1 and 4 initially declined, then remained low for two to three trials, and finally increased again to a level similar to that recorded before the birds were exposed to methiocarb. During the same period the average preference scores of both groups generally declined as the birds learned to discriminate between treated and untreated bunches.

When the locations of the treated and untreated bunches were alternated every day, the birds apparently could not distinguish which bunch was treated with methiocarb. The locations were alternated to prevent the birds from using a spatial cue and to force them to use some other type of cue (e.g. taste or vision) to detect which bunch was treated with methiocarb. Since the birds did not differentiate between methiocarb-treated and untreated bunches, they probably did not associate the taste, odour, or sight of the repellent (methiocarb left a white film on the surface of the grapes) with the toxic effects of the chemical.

The apparent failure of the birds in this study to become conditioned to the taste or sight of methiocarb suggests the possible irrelevance of these cues in the field. The amount of methiocarb on the grapes used in this test was probably similar to that on grapes treated at legal application rates in vineyards in the United States, as indicated from a previous study of methiocarb residues resulting from laboratory and field applications to wine grapes (M.E. Tobin and R.W. DeHaven, unpublished data).

When the treated grapes were always on the same side of the cage (i.e. during phases 2 and 3), the finches reduced their consumption from the treated bunches and did most of their feeding from the untreated bunches. Preference scores declined during phase 2 and remained low even during phase 3, when methiocarb was no longer applied to the grapes. The birds could not have relied solely on the taste, odour, or sight of the repellent, because none of these cues was present during phase 3. Thus, the evidence indicates that the house finches became conditioned to avoid the grape bunches based on the position of the bunch within the cage.

The visual tags did not enhance the repellency of methiocarb-treated grapes, nor were the tags themselves effective for repelling finches previously exposed to methiocarb-treated grapes in association with the tags. The particular type of tag employed in this experiment may have been inappropriate for use against house finches. For instance, birds are more sensitive to some colours than others (Donner, 1953), and perhaps colours other than yellow and brown would have been more appropriate. Many birds avoid yellow aposematic prey (e.g. Wigglesworth, 1968; Caldwell and Rubinoff, 1983), but other colours can also be effective (Brower, 1958a,b,c; Terhune, 1977; Brodie and Brodie, 1980). Red-winged blackbirds more readily form aversions to red than green when these colours are paired with ingestion of food followed by methiocarb-induced illness (Mason and Reidinger, 1983b), and red colouring has enhanced the repellency of methiocarb-treated fluid to silvereyes (Rooke, 1983). Perhaps red is also more effective against house finches.

The proximity of the tag to the grape bunch also may have influenced its effectiveness as a CS. Logue (1980) related the strength of conditioning of pigeons to the spatial proximity of the CS to the substance ingested. Cues that are applied directly to grapes might be more effective for enhancing repellency.

An understanding of how birds perceive and react to methiocarb-treated food is important for the most cost-effective use of this repellent. The degree to which birds can detect methiocarb on crops probably influences the size of area from which they are repelled. If wild house finches are unable to discriminate between methiocarb-treated and untreated grape vines, they may develop a general aversion to feeding in an entire vineyard, and partial treatments (e.g. spraying only borders or other selected rows in the vineyard) may provide substantial protection from this species. However, field studies are needed to verify whether such partial treatments are effective and, if so, to determine what proportion and spatial distribution of vines must be treated to obtain satisfactory protection.

Conclusions

The house finches in this experiment did not rely on the sight, taste, or odour of methiocarb for detecting and avoiding the ingestion of grapes treated with this repellent. Instead, the birds relied mainly on spatial cues. When the house finches could not distinguish between methiocarb-treated and untreated bunches, they formed a general aversion to both treated and untreated grapes. The birds formed a specific aversion to methiocarb-treated grapes only when the treated bunches were always in the same location. The cloth tags did not facilitate recognition and avoidance of grape bunches treated with methiocarb.

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